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Social and Physical Environmental Factors in Daily Stepping Activity in those with Chronic Stroke

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Abstract

Background, Purpose/Objective—Walking behavior in the chronic stroke population is multi-factorial. Previous work focused on the role of physical and biopsychosocial factors in understanding daily stepping post stroke. However, qualitative evidence suggests that social and physical environmental factors also affect daily stepping in those with stroke. The purpose of this study was to understand the role of social and physical environmental factors in daily stepping after stroke.

Methods—249 individuals ≥ 6 months post stroke were included in this cross-sectional analysis (129 females, mean age 62.98 years, SD 11.94). The social environment included living situation, work status, and marital status. The physical environment included the Area Deprivation Index (ADI) and Walk Score. At least three days of stepping was collected using an accelerometry-based device. Predictors were entered sequentially into a regression model: demographic characteristics, social environmental factors, and physical environmental factors.

Results—After adjusting for demographic factors, social environmental factors explained 6.2% (p= .017) of the variance in post stroke daily stepping. The addition of physical environmental factors improved the model (ΔR^2 = .029, p = .024). The final model explained 9.2% (p=.003) of the variance in daily stepping. Lower area deprivation (ADI β= −0.178, p= .015) and working (working vs. retired β= −0.187, p= 0.029 and working vs. unemployed β= −0.227, p=.008) were associated with greater daily stepping.

Discussion/Conclusion—Social and physical environmental factors predicted daily stepping and should be considered when setting expectations relative to the effects of rehabilitation on daily stepping in individuals poststroke.

Keywords

stroke; walking; physical activity; environment

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Declaration of Interest Statement
The authors report no conflict of interest.

INTRODUCTION

It is well understood that reduced levels of physical activity (PA) after stroke are associated with an increased risk for cardiovascular disease and recurrent stroke.[1–3] Evidence has shown that individuals post stroke are less physically active than healthy age-matched counterparts.[4,5] A recent study found that in a sample of 274 individuals post stroke, 69% of waking hours were spent in sedentary activities.[6] Another study including 79 individuals at least 6 months post stroke observed that participants took on average 1,389 steps per day[7] which could be classified as a "sedentary lifestyle" using criteria outlined by Tudor-Locke et al.[8] Previous work has demonstrated that reducing the amount of time spent sedentary can reduce metabolic risk factors associated with cardiovascular disease.[9] One approach to reducing the amount of time spent sedentary is to improve walking activity levels. Thus, it is important to understand factors that contribute to walking activity post stroke to enable clinicians to provide targeted intervention strategies and reduce one's risk for recurrent stroke and other negative health outcomes.

Recent work aimed at understanding factors associated with reduced physical activity levels post stroke have been limited by issues such as low sample size and by a lack of representation of important domains thought to be related to daily stepping. To date, studies have analyzed predominantly mobility factors (i.e. measures of walking capacity, such as gait speed and gait endurance)[10–12] and biopsychosocial factors (i.e. depression, self-efficacy)[13,14] with limited investigation of the environmental domain[12,15]. However, these models leave much of the variance in post stroke daily stepping unexplained. A recent meta-analysis found that measures of physical capacity, specifically the Six Minute Walk Test, generally explain 37% of the variance in post stroke physical activity.[12] The addition of biopsychosocial factors contributes additional explained variance but still represents an incomplete understanding of post stroke daily stepping.[13] Thus, it is important to examine other variables that likely influence real world daily stepping in those post-stroke in the real world.

Qualitative evidence indicates that perceived environmental barriers affect walking activity in the post stroke population.[15–18] In a study using interview and focus group techniques, stroke survivors expressed that social (e.g. feeling "held back" by the safety concerns of their caregiver) and physical (e.g. the presence of uneven surfaces and crowds) environmental factors impacted their outdoor walking activity.[17] In an explanatory mixed-methods study by Barclay et al, adaptation to a quantitative model was required to include environmental barriers after qualitative feedback from stroke survivors was received indicating the importance of this domain.[19] Based on these results, it seems plausible that some of the unexplained variance observed in studies analyzing solely mobility and biopsychosocial factors may be attributed to lack of consideration for the environmental domain.

To measure aspects of the physical environment previous work has used the Area Deprivation Index to measure levels of area deprivation and the Walk Score to measure neighborhood walkability. Previous studies have included measures of area deprivation in models evaluating risk factors associated with stroke[20,21]; however, less is known about how (or if) area deprivation and socioeconomic status affect daily stepping activity and this has not been examined after stroke. Contradictory evidence exists as to role of neighborhood walkability in understanding daily stepping activity. Hajna et al found that neighborhood walkability, measured using the Walk Score, was not associated with greater amounts of daily stepping measured via accelerometry and through self-report in a large sample of individuals living in Canada.[22] Conversely, Twardzik et al found that adults living in a Walk Score area of 'Very Walkable/Walker's Paradise' across various regions within the United States was associated with a greater amount of daily time spent in moderate to vigorous physical activity.[23] Likewise, Duncan et al found that neighborhood walkability was associated with greater stepping activity measured via accelerometry in a sample of Paris adults.[24] Thus, in this study, we sought to understand how area deprivation and neighborhood walkability affect daily stepping in those with chronic stroke.

The purpose of this study was to specifically understand the role of social and physical environmental factors in explaining daily stepping after stroke. Based on qualitative evidence demonstrating the role of perceived environmental barriers in understanding walking activity in those post stroke, we hypothesized that social and physical environmental factors would result in a significant contribution of explained variance in daily stepping, as measured quantitatively, after stroke.

METHODS

Participants

Data for this study was obtained from baseline measurements of a larger randomized controlled trial with 4 sites (NCT02835313): University of Delaware, University of Pennsylvania, Christiana Care Health System, and Indiana University.[25] Individuals aged 21–85 and at least 6 months post-stroke were included in this trial. For this study, additional inclusion criteria included: (1) able to walk without assistance from another person (assistive devices allowed) at a gait speed of at least 0.3 m/s, (2) resting heart rate between 40–100 beats per minute, and (3) resting blood pressure between 90/60 to 170/90 mmHg. Individuals were excluded from this study if they met any of the following criteria: (1) evidence of cerebellar stroke, (2) other potentially disabling neurologic conditions in addition to stroke, (3) received lower limb Botulinum toxin injection <4 months earlier, (4) current participation in physical therapy, (5) inability to walk outside the home before their stroke, (6) coronary artery bypass graft, stent placement, or myocardial infarction within the past 3 months, (6) musculoskeletal pain limiting activity, (7) inability to communicate with the investigators. All participants received medical clearance prior to participating in the randomized clinical trial and signed an informed consent approved by the Human Subjects Review Board at the University of Delaware prior to study participation. During the baseline study visit, the participant's demographic information, characteristics of their stroke, and whether or not they used an assistive or orthotic device were collected via self-report. The participant's gait speed (10-Meter Walk Test) and gait endurance (6-Minute Walk Test) were also measured at the baseline study visit.

Walking Activity

Walking activity was quantified as average steps per day and was collected during all waking hours (except during bathing) using the FitBit One™ or FitBit Zip™ that was placed on the participant's non-paretic ankle. The accuracy of the FitBit™ has been previously demonstrated to be acceptable in those post stroke across a range of impairment levels.[26–29] Participants were instructed to continue with their usual activity and wear the FitBit™ until their next study visit. A minimum of 3 days of step data was recorded to reliably estimate daily stepping activity.[30] The maximum number of stepping days collected varied based on the amount of time between study visits of the pre-intervention phase. During analysis of stepping data, if it was questionable if the participant wore the FitBit™ for all waking hours on a particular day, the participant was queried to understand if adherence to FitBit™ wear time was maintained. A determination on whether to include the day was based on the participant's response and by comparing wear time on the day in question to other stepping days. Any days in which it was determined that the participant did not wear the FitBit™ during all waking hours were removed from calculations of their daily average stepping. Average steps per day was calculated by summing the total number of steps from all valid stepping days and dividing this sum by the total number of valid stepping days.

Environmental Factors

This study focused specifically on the role of social and physical environmental factors in daily stepping in those post stroke. The following variables were considered to represent the social environmental domain: (1) marital status, (2) living situation, and (3) work status. Marital status was categorized as either married or not married (not married included those who were single, widowed, separated, or divorced). Work status was categorized as working full or part-time, retired, or unemployed. Living situation was categorized as living alone or with a family member/significant other. This information was obtained during the participant's first study visit.

The Walk Score and Area Deprivation Index were used to represent the physical environmental domain. The Walk Score is determined through a publicly available website that uses a geographically-based algorithm to provide an estimate of neighborhood walkability based on proximity of an address to 13 amenity categories, including grocery stores, coffee shops, restaurants, bars, movie theatres, schools, parks, libraries, book stores, fitness centers, drug stores, hardware stores, and clothing/music stores.[31] Each of the amenity categories are equally weighted, summed and normalized to produce a score from 0–100, where scores from 0–24 represent living in a "car-dependent" area where almost *all* errands require a car, scores 25–49 represent living in a "car-dependent" area where *most* errands require a car, scores 50–69 represent living in a "somewhat walkable" area where some errands can be accomplished on foot, scores 70–89 represent living in a "very walkable" area where most errands can be accomplished on foot, and scores 90–100 represent living in a "walker's paradise" in which a car is not required for daily errands.[31,32] The Walk Score has been shown to be a valid measure of estimating neighborhood walkability.[31,32] The Area Deprivation Index (ADI) is a composite index of neighborhood socioeconomic disadvantage that uses various indicators of poverty, education, housing, and employment within regions of the United States.[33] The ADI provides a national percentile ranking from 1–100, with 1 representing the lowest level of disadvantage within the nation and 100 representing the highest level of disadvantage.[34] Previous work has demonstrated that the ADI is a valid measure of neighborhood disadvantage in the United States.[35] Area deprivation has been shown to be predictive of diabetes, cholesterol, and blood pressure control as well as risk for adverse health outcomes, such as cardiovascular mortality, in the general population.[35,36] The participant's home address was used to obtain the ADI (https://www.neighborhoodatlas.medicine.wisc.edu/) and Walk Score (https://www.walkscore.com/).

Statistical Analysis

Marital status was coded as either married [0] or not married [1]. Living situation was coded as either living with a family member/significant other [0] or living alone with or without outside assistance [1]. Work status was coded as working full or part-time [0], retired [1], or unemployed (included being in disability) [2]. Work status was then dummy coded as working vs. retired and working vs. unemployed. Sequential linear regression was used to examine the relationship between social and physical environmental factors and daily stepping post stroke while adjusting for the demographic variables of age and gender. In the regression models, successive blocks of predictors are entered into the model to see if the newly entered variables show a significant improvement in the amount of explained variance in the model.[37] Predictors were entered in the following order: demographic characteristics (block 1: age, gender), social environmental factors (block 2: marital status, work situation, living situation), and physical environmental factors (block 3: ADI, Walk Score). The change in R^2 was tested after each block entry to see if its respective group of predictors was significantly related to average steps per day.

All assumptions were tested. The model initially violated the assumption of normality due to positive skewness and the presence of outliers. Removing the most extreme outliers did not remedy the violation. Therefore, a square root transformation of steps per day was employed. Doing so satisfied all assumptions. All analyses were performed using SPSS (Version 25.0; Armonk, NY, USA) with $\alpha=0.05$. This manuscript conforms to the STROBE Guidelines.

RESULTS

Data were obtained from an existing database from the four-site randomized controlled trial.[25] Data were available from 249 participants at the time of this analysis, but the parent project remains on-going. This sample was on average 63 years of age and time since stroke was 47 months (Table 1), and contained representation from the full range of Walk Score values (range 0–100, mean 33, SD 28) as well as Area Deprivation Index values (range 1–100, mean 37, SD 24), see Table 2. For the Walk Score, 187 individuals lived in a "car-dependent" area, 31 lived in a "somewhat walkable" area, 22 lived in a "very walkable" area, and 9 lived in a "walker's paradise" area. There was substantial inter-subject variability in average steps per day (range 76–18166, mean 4543, SD 2793). The average number of valid step days was 9 (range 1–26, SD 4), and the maximum number of days of stepping data collected was 26. A greater proportion of participants lived with a family member or significant other (79.1%), were retired (49.8%), and married (55.8%), see Table 3. During the baseline visit of the clinical trial, measures of the participant's gait speed (10 Meter Walk Test) and gait endurance (6 Minute Walk Test) were collected, and these values are reported in Table 1 for purposes of characterizing the study sample.

Supporting our initial hypothesis, the addition of social environmental factors into the model after adjusting for demographic factors significantly improved the model ($\Delta R^2 = .049$, $p = .015$), (Table 4). After adjusting for both demographic factors and social environmental factors, the addition of physical environmental factors significantly improved the model further ($\Delta R^2 = .029$, $p = .024$). In total, the model R^2 was 9.2% (p=.003). In the full model, the Area Deprivation Index was negatively related to steps per day (β= −0.178, p= .015), and the dummy codes for being retired (β= −0.187, p= 0.029), and unemployed (β= −0.227, p=.008) were significant (Table 5). Unlike the ADI, the Walk Score did not significantly contribute to daily stepping. Tests for collinearity indicated that multicollinearity was not a concern (Age: Tolerance 0.58, VIF 1.723; Gender: Tolerance .918, VIF 1.089; Working vs. Retired: Tolerance: .531, VIF 1.882; Working vs. Unemployed: Tolerance .539, VIF 1.855; Living: Tolerance .693, VIF 1.444; Marital: Tolerance .587, VIF 1.702; ADI: Tolerance .733, VIF 1.365; Walk Score: Tolerance .699, VIF 1.43).

DISCUSSION

The purpose of this study was to examine the role of social and physical environmental factors in explaining walking activity, measured in average steps per day, in those post stroke. We hypothesized that social and physical environmental factors would be significant contributors to the variance in average steps per day in those with chronic stroke. In support of our hypothesis, the unique addition of both social and physical environmental factors into our model were significant. The results indicate that working and living in a less socioeconomically deprived neighborhood are associated with greater daily stepping after stroke. These results facilitate a more complete understanding of post stroke daily stepping and demonstrate the importance of considering social and physical environmental factors when prescribing interventions and setting expectations relative to improving daily stepping in the chronic stroke population. For example, understanding that living in an area of greater area deprivation was associated with less steps per day, a clinician may provide a patient living in these areas with a list of community resources to consider, such as fitness or community centers, to facilitate greater steps per day.

In our model, the addition of social environmental factors (collectively, work status, living situation, and marital status) was significant. Working (as opposed to being retired or unemployed), living alone (with or without outside assistance), and being married were associated with greater steps per day. These results are in line with previous work demonstrating that one's living situation and marital status can affect walking behavior in the stroke population.[17,38] For example, living alone and/or being the primary provider for household tasks has been positively associated with greater activity levels.[17,38,39] Similarly, living with a supportive significant other or family members may also provide less walking opportunities if household or other daily tasks are absorbed by others. The presence of social support has been positively associated with physical activity levels in the stroke population through providing encouragement and assistance (when needed) to walk.[40] However, the presence of members of a social support system who are overly protective has also been associated with reduced physical activity levels.[40] The results from our study add to this knowledge through demonstrating that living alone and being married are associated with greater daily stepping after stroke.

Previous evidence in adults with and without type 2 diabetes mellitus has shown that there may be a relationship between employment status and activity levels.[41] The results from our study demonstrate that individuals post stroke who were retired or unemployed had lower steps per day compared to those who were working full or part-time. Conceptually, this makes sense as being employed likely involves some degree of walking activity throughout the day as well as transportation to/from a place of employment which may increase one’s opportunities for daily stepping.

To our knowledge, this is the first study to include the Walk Score and Area Deprivation Index in a model aimed at understanding objectively measured daily stepping in the chronic stroke population. Unlike the ADI, the Walk Score was not statistically significant in our model, suggesting that neighborhood walkability was not associated with daily stepping in those with stroke and this may have occurred for several reasons. Previous studies have reported contradictory findings that neighborhood walkability does[23,24] and does not[22] affect daily stepping in the general population and these studies have also been conducted in various geographical regions. Consequently, there may be a geographical component of walkability that may explain the differences in findings across some studies. To add to this complexity, the relationship between neighborhood walkability and actual walking activity may be different in otherwise healthy populations compared with the chronic stroke population. However, further work is needed to fully elucidate the relationship between neighborhood walkability and daily stepping those with stroke.

The results of this study suggest that living in an area of greater deprivation is associated with lower daily stepping in those with stroke. Recent evidence has alluded to the potential role of socioeconomic factors in understanding exercise habits in the stroke population.[42] Thus, it is reasonable to infer that these factors may play a role in daily stepping and this is supported by the results of this study. However, future studies with large sample sizes spanning numerous geographical regions are needed to confirm the results found in this study.

An important consideration for the results of this study is that some environmental factors may not be modifiable, such as the circumstances around one’s living situation. However, understanding that factors such as working and living in an area with lower area deprivation are associated with greater daily stepping in those with stroke provides evidence that clinicians should consider screening for these factors when attempting to improve daily stepping in their patient with stroke. For example, a clinician may discuss with a patient any opportunities to return to work in a modified capacity and how this may positively influence their daily stepping. Alternatively, if it is determined that area deprivation is affecting a stroke survivors’ ability to achieve greater daily stepping, a clinician may provide a list of community resources that could provide greater opportunities for daily stepping.

Despite evidence indicating the importance of the environmental domain in walking activity levels post stroke, our final model explained a very small percentage of the variance in steps per day in this population. There are several reasons for why this may be the case. Although we selected the variables of work status, living situation, and marital status to represent the social environmental domain, there may be alternative measures that more inclusively represent this construct. Other measures of the social environmental domain, such as caregiver perceptions of a stroke survivor's abilities, may be of greater (or additional) importance in understanding the role of social environmental factors in daily stepping post stroke.[17] Likewise, previous work has shown that there may be certain characteristics of the physical environment that are perceived by stroke survivors as a greater barrier over others.[15,16] Thus, there are likely aspects of physical environment that are not captured by the measures used in this study.

Walking behavior in those with stroke is likely multi-factorial with varying degrees of contribution from physical factors, biopsychosocial factors, and environmental factors.[12] Thus, the use of more advanced analytical models may help capture the role of the environment and its interplay with other important domains in understanding post stroke walking behavior. Approaches such as structural equation modeling (SEM) may provide additional insight into the inter-relationships between the many variables that contribute to daily stepping post stroke.[43]

Potential Limitations

This study had several limitations. First, this analysis included only individuals who were at least 6 months post stroke and were able to walk at least 0.3 m/s. Consequently, our results may not be generalizable to those outside of these criteria. We also acknowledge that we were limited to measures available within the larger clinical trial from which our dataset was extracted. Although specific criteria were used to determine what constituted a valid stepping day, data related to average wear time was not collected. Finally, other measures of the environment, such as inclement weather, may affect physical activity and were not directly measured in this study.

Conclusions

Measures of the social and physical environment were significant in our model aimed at understanding the role of the environment in daily stepping in the chronic stroke population. Individually, the Area Deprivation Index and level of work status were statistically significant. Although clinicians are often unable to modify some of these environmental factors, our study suggests that they should be of consideration when providing resources and setting expectations relative to the effects of rehabilitation on daily stepping in individuals with chronic stroke

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Table 1:

Demographic Characteristics of Study Sample

Age, yrs	Mean: 62.98 (11.94) Range: 25–85
Gender	Male: n = 120 (48.2%)
Side of Hemiparesis	Left: 133 (53.7%), Right: 109 (43.9%), Bilateral: 6 (2.4%)
Time Since Initial Stroke, mo	Mean: 47.47 (60.21) Range: 6 – 480
Self-selected Gait Speed, m/s	Mean: 0.71 (0.21) Range: 0.30 – 1.06
Walking Endurance (6 Minute Walk Test, m)	Mean: 299.9 (117.53) Range: 40.28 – 602.36
Assistive Device, yes/no	Yes: n = 122 (49%)
Orthotic, yes/no	Yes: n = 60 (24.1%)

Table 2:

Descriptive Statistics for Continuous Variables of Interest

	Range	Mean (SD)
Average Steps per Day (SPD)	76 – 18166	4543 (2793)
Walk Score	0 – 100	33 (28)
Area Deprivation Index (ADI)	1 – 100	37 (24)

Table 3.

Descriptive Statistics for Categorical Variables of Interest

	Frequency	Percent
Living Situation		
Alone	52	20.9
Not Alone	197	79.1
Work Status		
Full/Part Time	56	22.7
Retired	123	49.8
Unemployed	68	27.5
Marital Status		
Married	139	55.8
Not Married	110	44.2

Table 4:

Results of Sequential Linear Regression Predicting Daily Stepping Post Stroke

Block	Predictors	R^2	Model *P*	ΔR^2	ΔR^2 *P*
1	Demographics	0.013	0.206	0.013	.206
2	Demographics + SEF	0.062	0.017*	0.049	.015*
3	Demographics + SEF + PEF	0.092	0.003*	0.029	.024*

Abbreviations: SEF, Social Environmental Factors; PEF: Physical Environmental Factors.

*Denotes significance at $P < 0.05$

Table 5:

Standardized Regression Coefficients of Final Sequential Linear Regression Model

	Predictor	β	*P*
	Age	−0.134	0.102
	Gender	−0.035	0.590
	Living Situation	0.101	0.176
	Working vs. Retired	−0.187	0.029 *
	Working vs. Unemployed	−0.227	0.008 *
	Marital Status	−0.080	0.321
	ADI	−0.178	0.015 *
	Walk Score	−0.002	0.975

Abbreviations: ADI, Area Deprivation Index

* Denotes significance at P < 0.05